

A Software Framework for Mobile Ad hoc Data Communications Using Voice-Centric Tactical Radios



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Motivation

- State of Practice: Modern C2 capabilities often don't reach front line troops
 - situation awareness still voice centric
 - transition to information centric operation limited by legacy stove-pipe system designs
- State of Art: Mobile ad hoc networking is becoming a commodity technology in the civilian sector
 - ubiquitous high speed access to multimedia
 - minimum configuration



Research Objectives

- Investigate feasibility of providing data networking capability to small units with legacy radios
- Minimize requirement for additional “networking hardware”

Proof of Concept via SINCGARS Radio





System Components

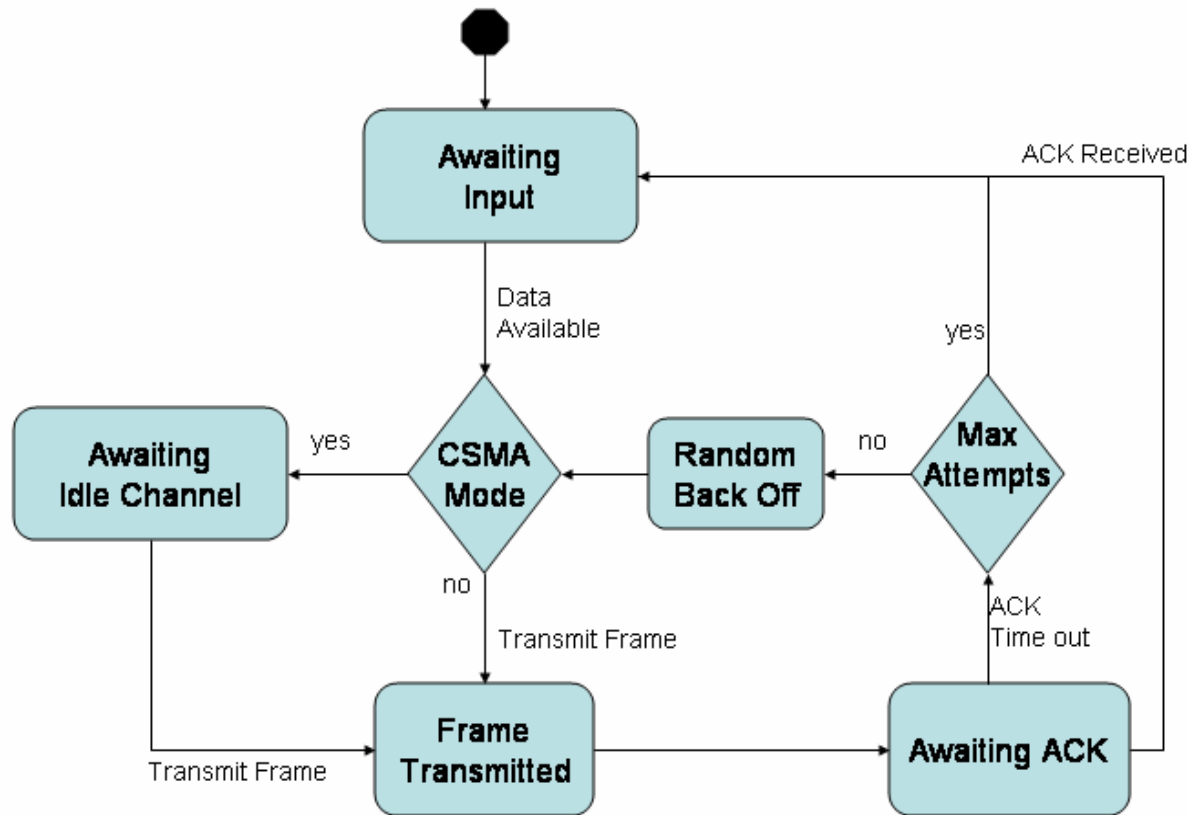
- Data Link Protocol
- Multi-hop Routing Capability
 - Expected Relative Positioning Routing with Congestion Avoidance (ERP/CA)
- Tactical Chat Application
 - SINCGARS Data Demo



Data Link Protocol

- Media Access Control
 - ALOHA & CSMA Functionalities
- Flow Control and Error Control
 - Simple Stop-and-Wait
- “802.11-Lite”
 - Minimum subset of 802.11 features
 - MAC, Encapsulation, Error Control
 - No sync, beacons, probes, NAVs, authentication, etc.

Media Access Control





ERP/CA Routing Protocol

- Operation-aware
 - Exploit Operational Knowledge about Node Movements
- Bandwidth-Efficient
 - Minimize Overhead of Control Traffic



Operational Knowledge

- TTPs (Tactics, Techniques, and Procedures) Used by Tactical Units
 - Military formations
 - Wingman concept
- Unit Leaders Maintain Physical Proximity
 - Maintain Radio Contact
 - Facilitates Command and Control



Operation-aware Routing

- Route Selection Based Upon Relative Positions of Nodes Within Formation
 - Relative positions between nodes (or node relationships) are policy-driven
 - Links between nodes with “close” relationship tend to be persistent
- Mechanism: Nodes wait for a period of time before responding to route request
 - Node with closest relationship to destination responds to route request first



Route Response Wait Formula

$$RRW = CW + CAV + IRW \quad \text{milliseconds}$$

CW values:

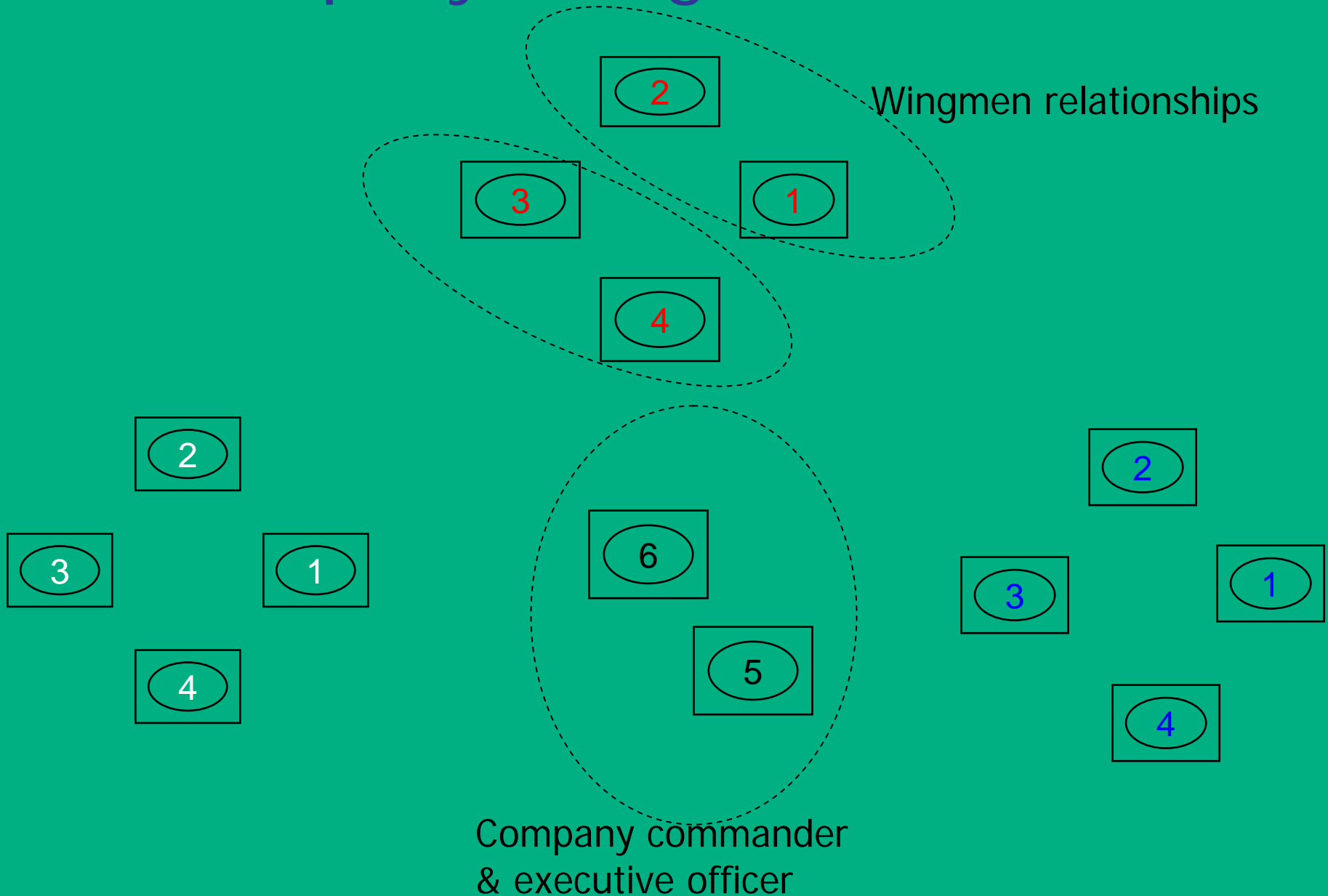
Relationship Category	Wait Time Assigned (ms)
GOOD	1500
BETTER	1000
BEST	500
DIRECT LINK	0



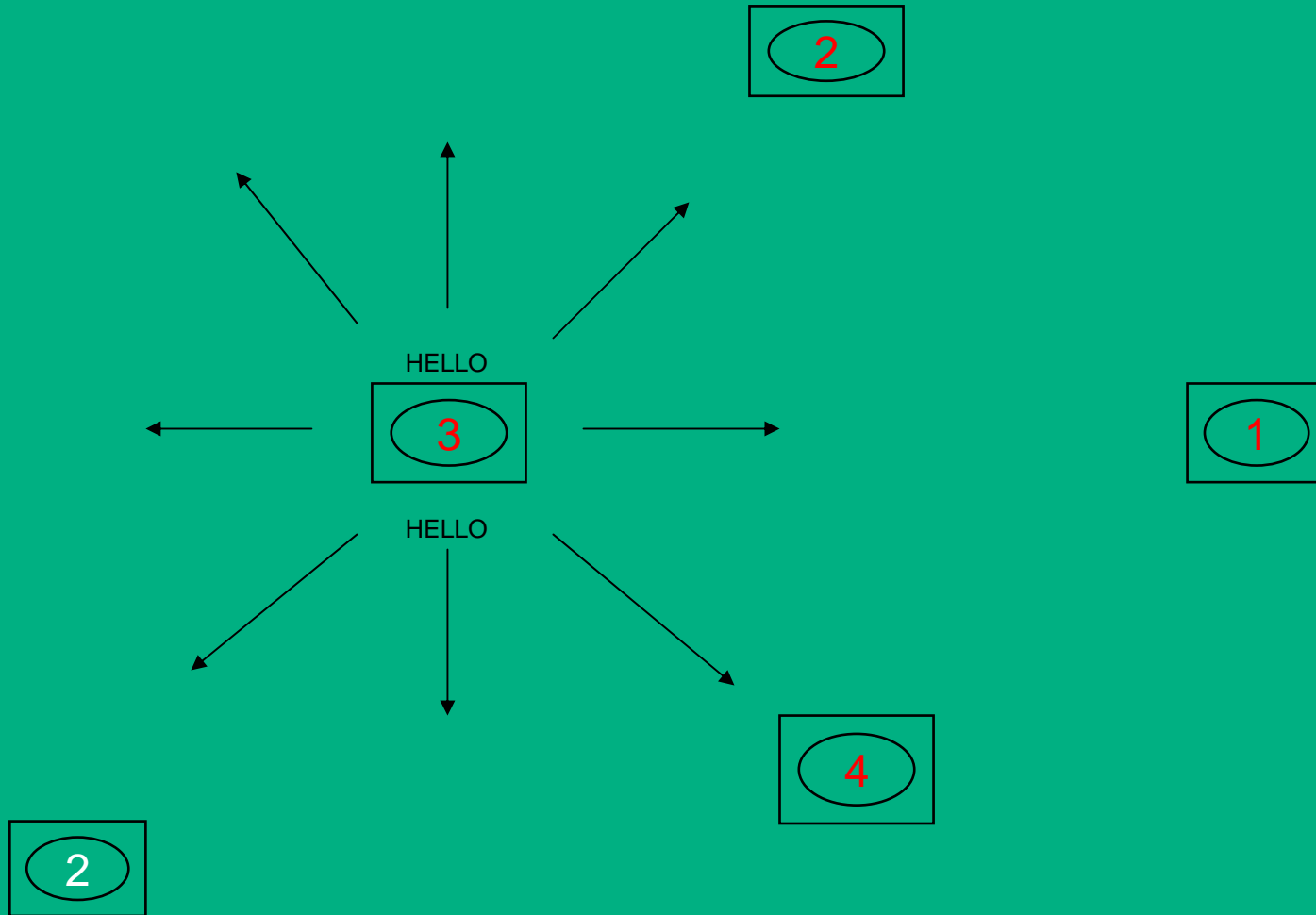
Bandwidth-Efficient Routing

- On-demand Route Discovery
- Controlled Flooding
 - Node stops flooding if it has route to destination
- Node Relationships are Input to Protocol
 - No need to discover them (**this is novel!**)

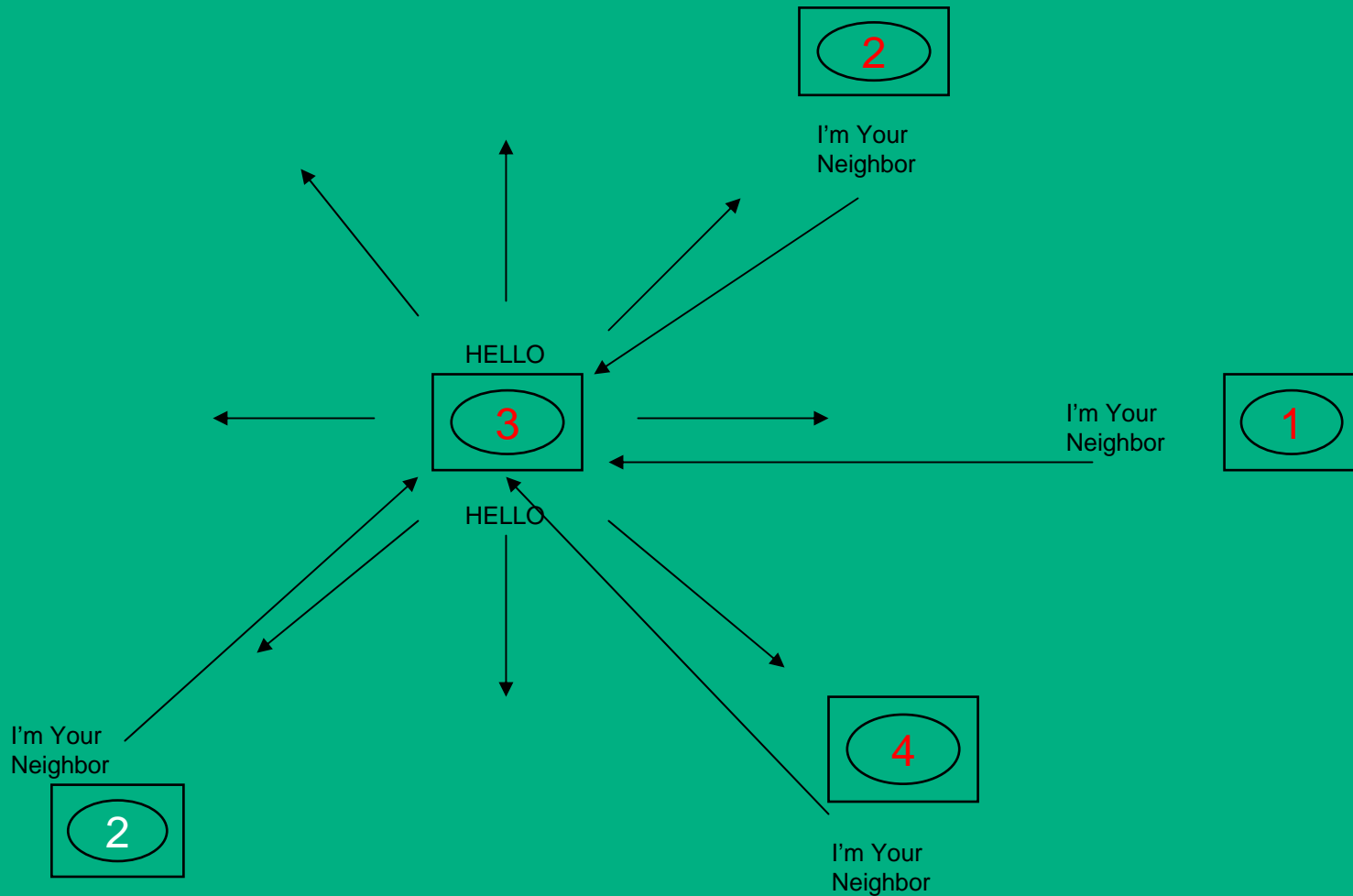
Tank Company Wedge Formation

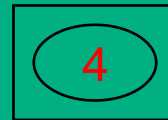
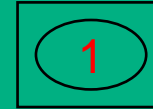
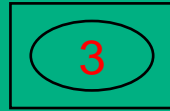
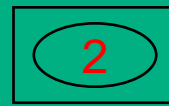


Neighbor Discovery

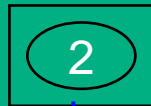


Neighbor Discovery (HELLO Response)



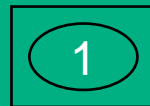
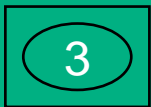


Source

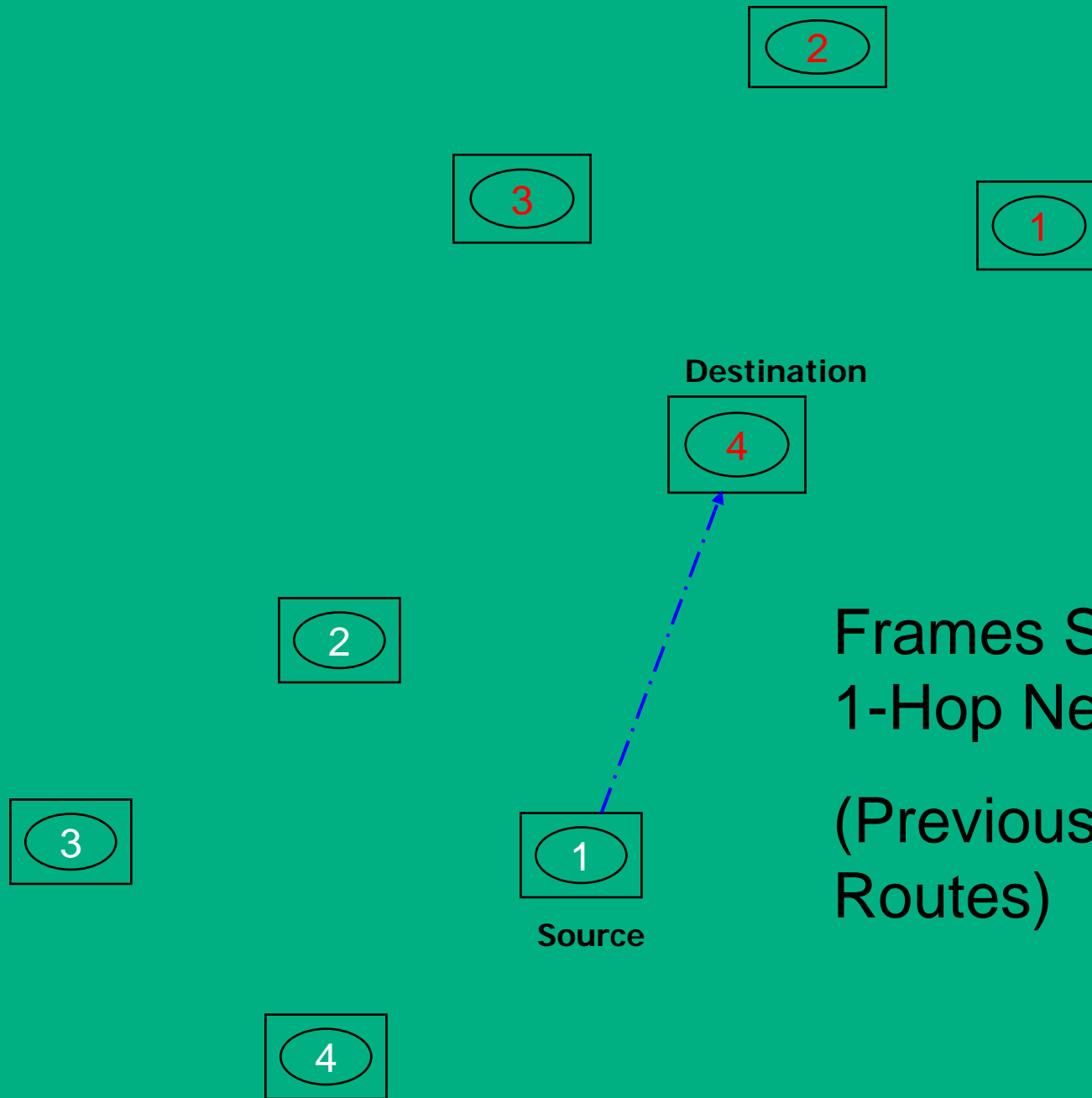


Frames Sent Between
1-Hop Neighbors

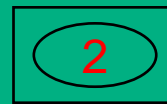
(Previously Known
Routes)



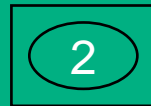
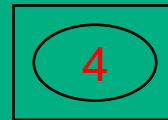
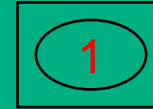
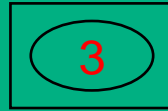
Destination



Frames Sent Between
1-Hop Neighbors
(Previously Known
Routes)

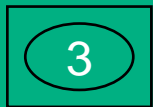


Destination

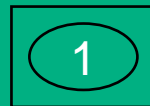


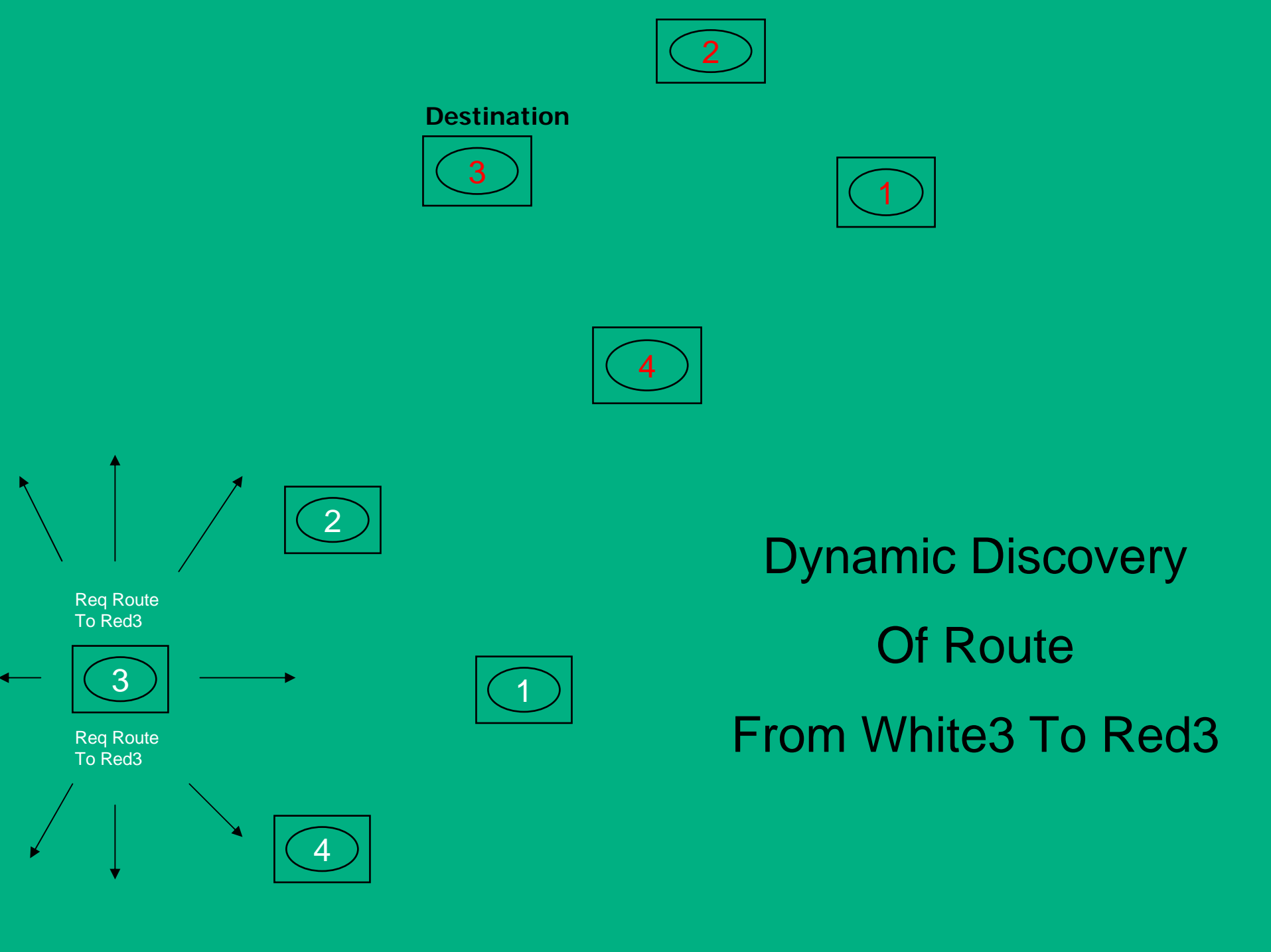
Frames Sent Between
Multi-Hop Neighbors

(Dynamic Discovery
Of Routes)

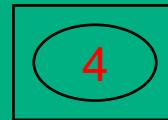
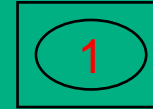
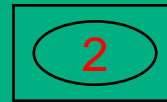
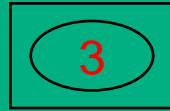


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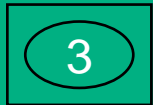
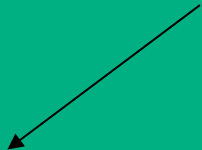
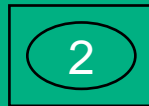




Destination

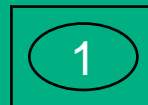


I can reach
Red3



source

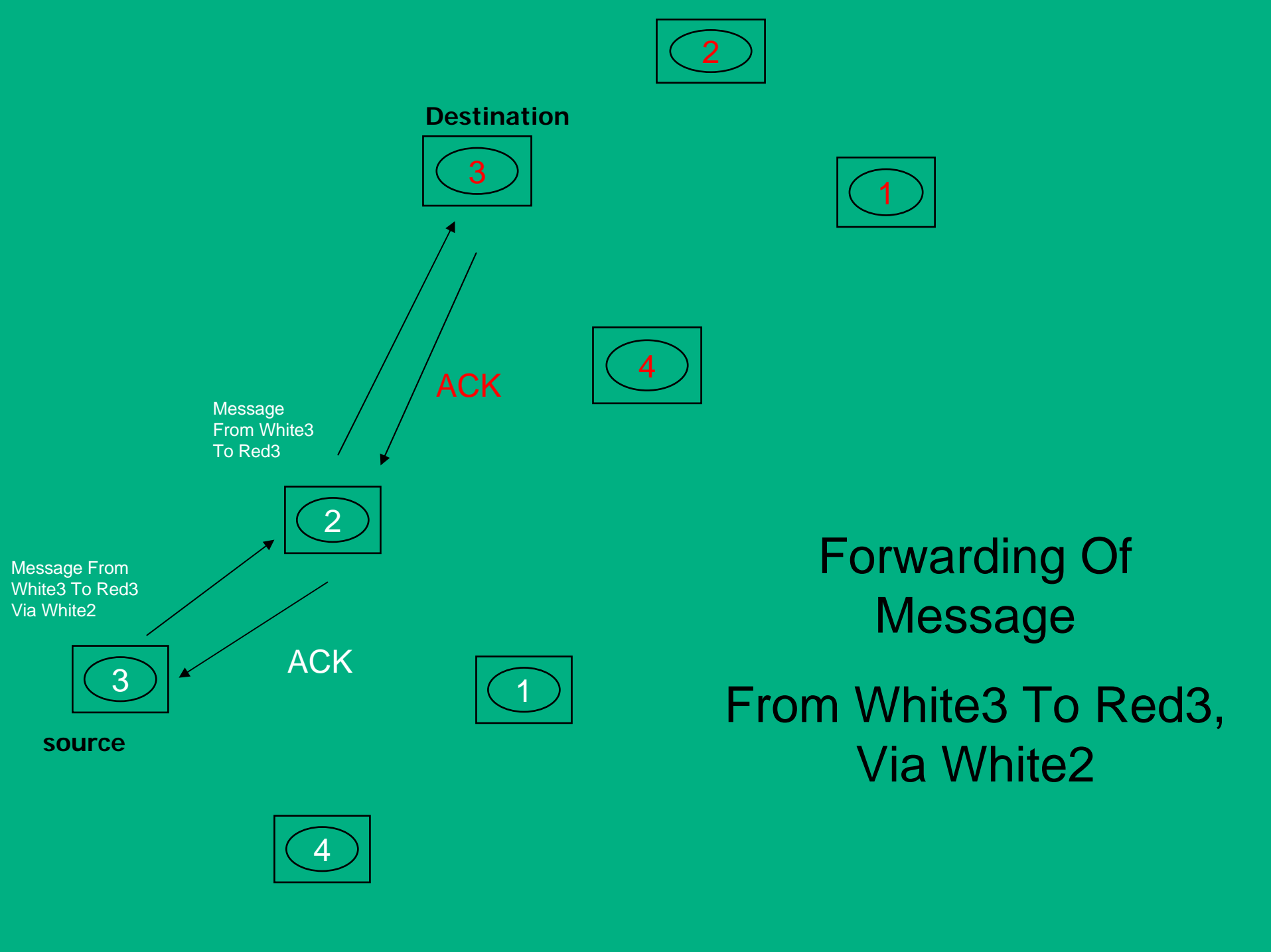
No route.
No response



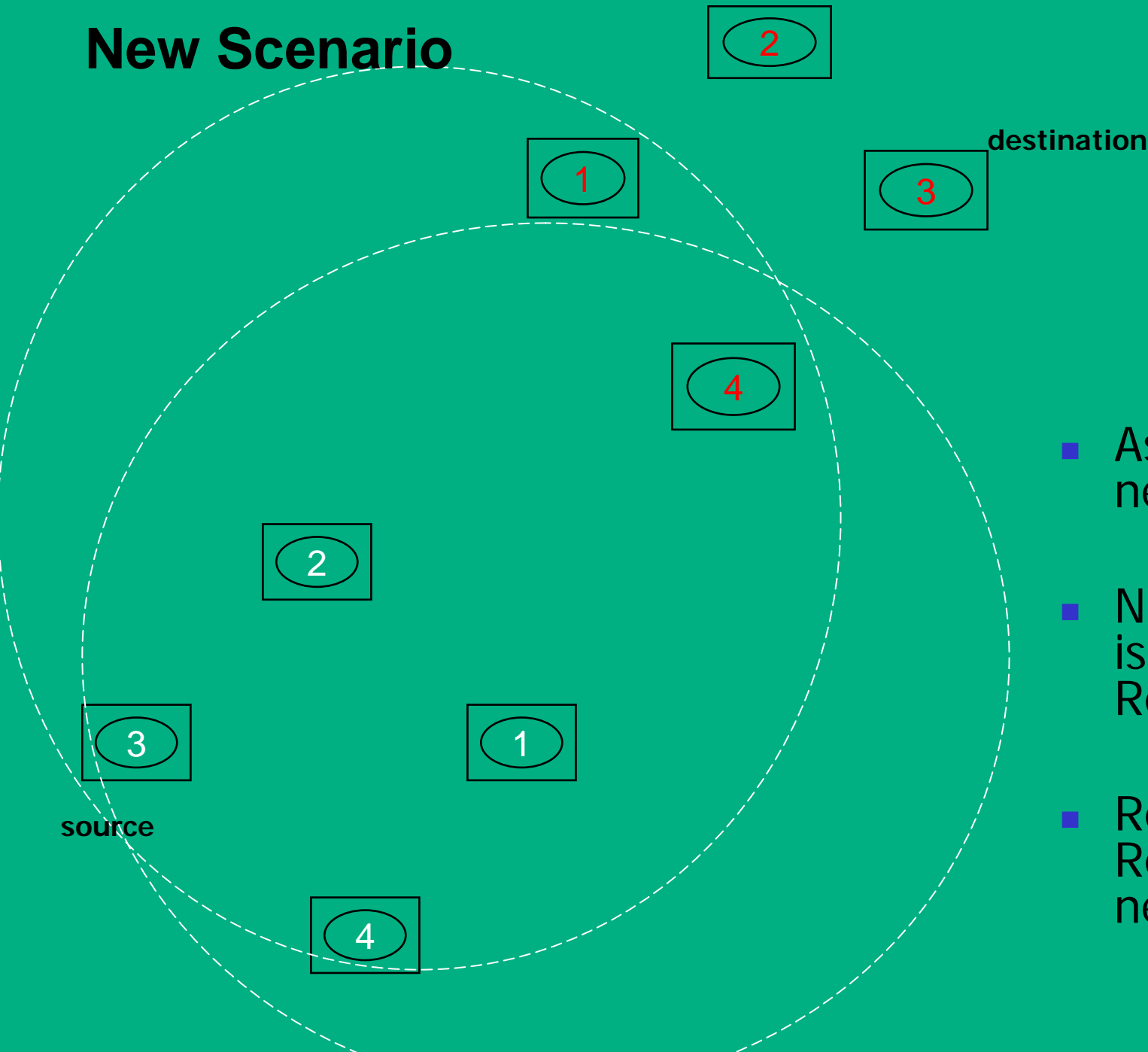
No route.
No response



Dynamic Discovery
Of Route
From White3 To Red3

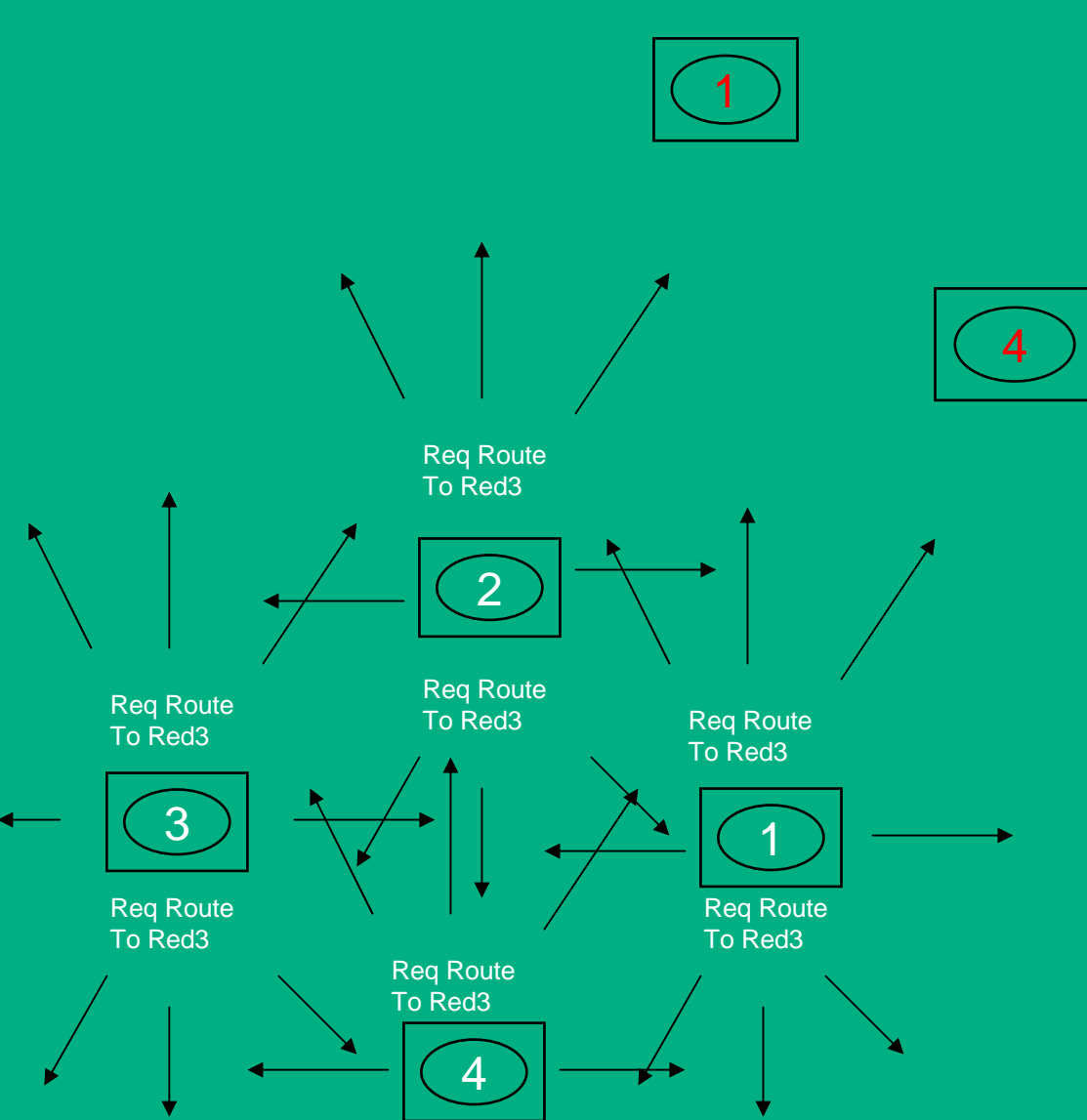
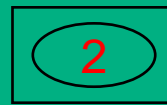


New Scenario



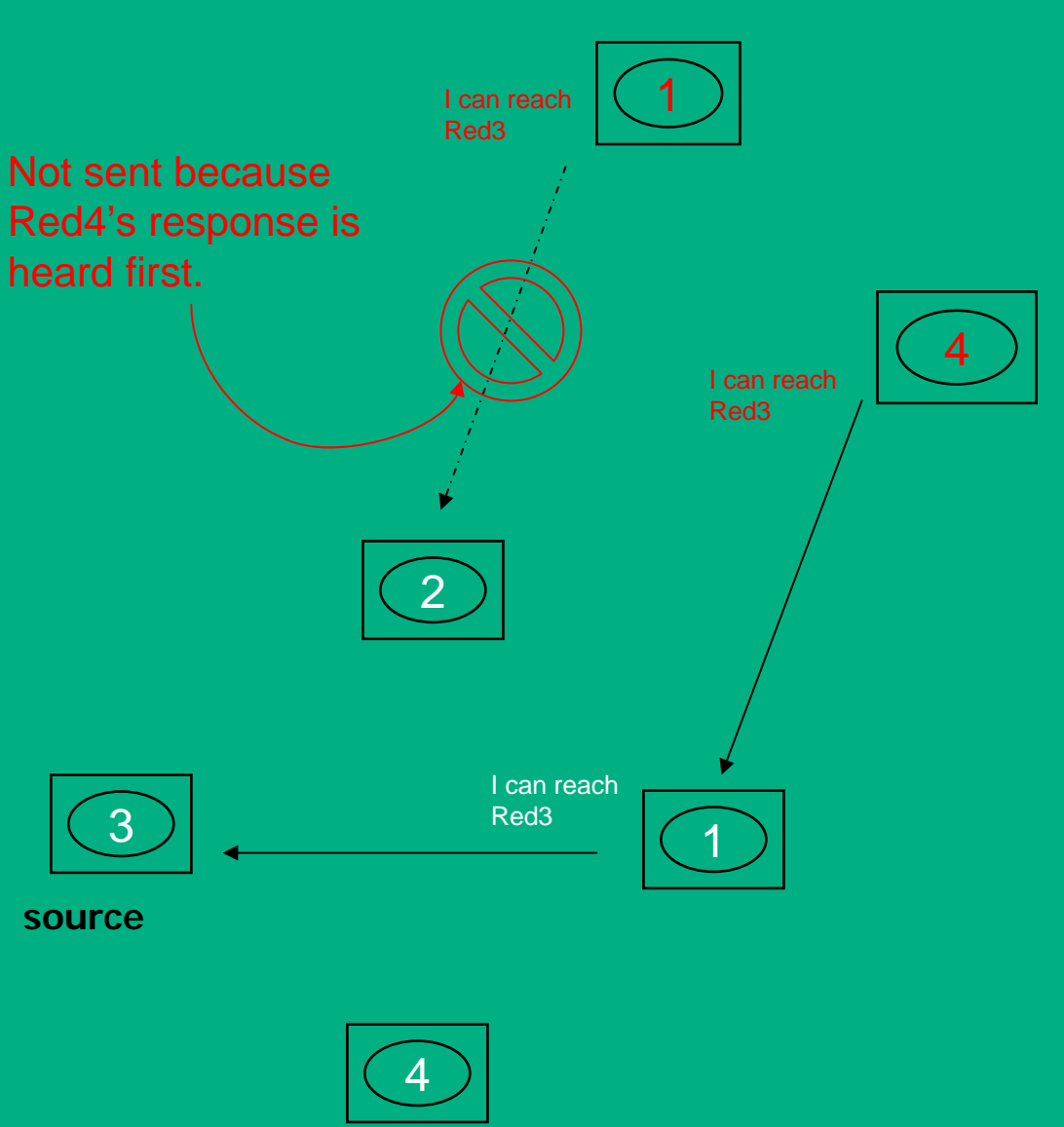
- Assume this new state:
- No white node is in range of Red3
- Red3 and Red1 are in new positions

Dynamic Route Discovery



- Requests are broadcasted and flooded
- TTL limits life of flood
- Route response ends flooding

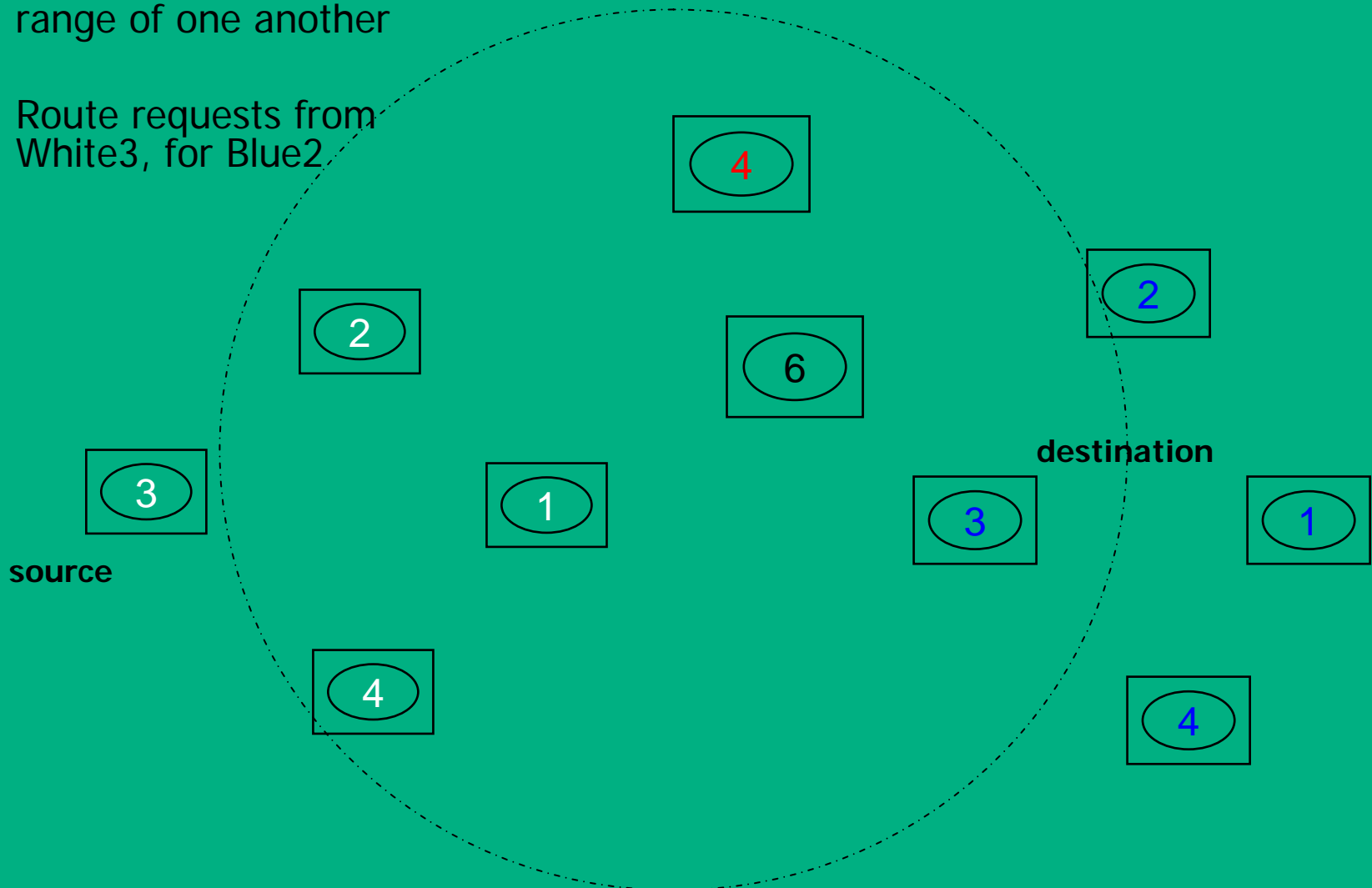
Response To Route Request



- All response are unicast
- Responses are based on categories
- Actual destination responds first
- Wingman responds next
- Followed by Platoon Commander
- Last to respond are all others with a route

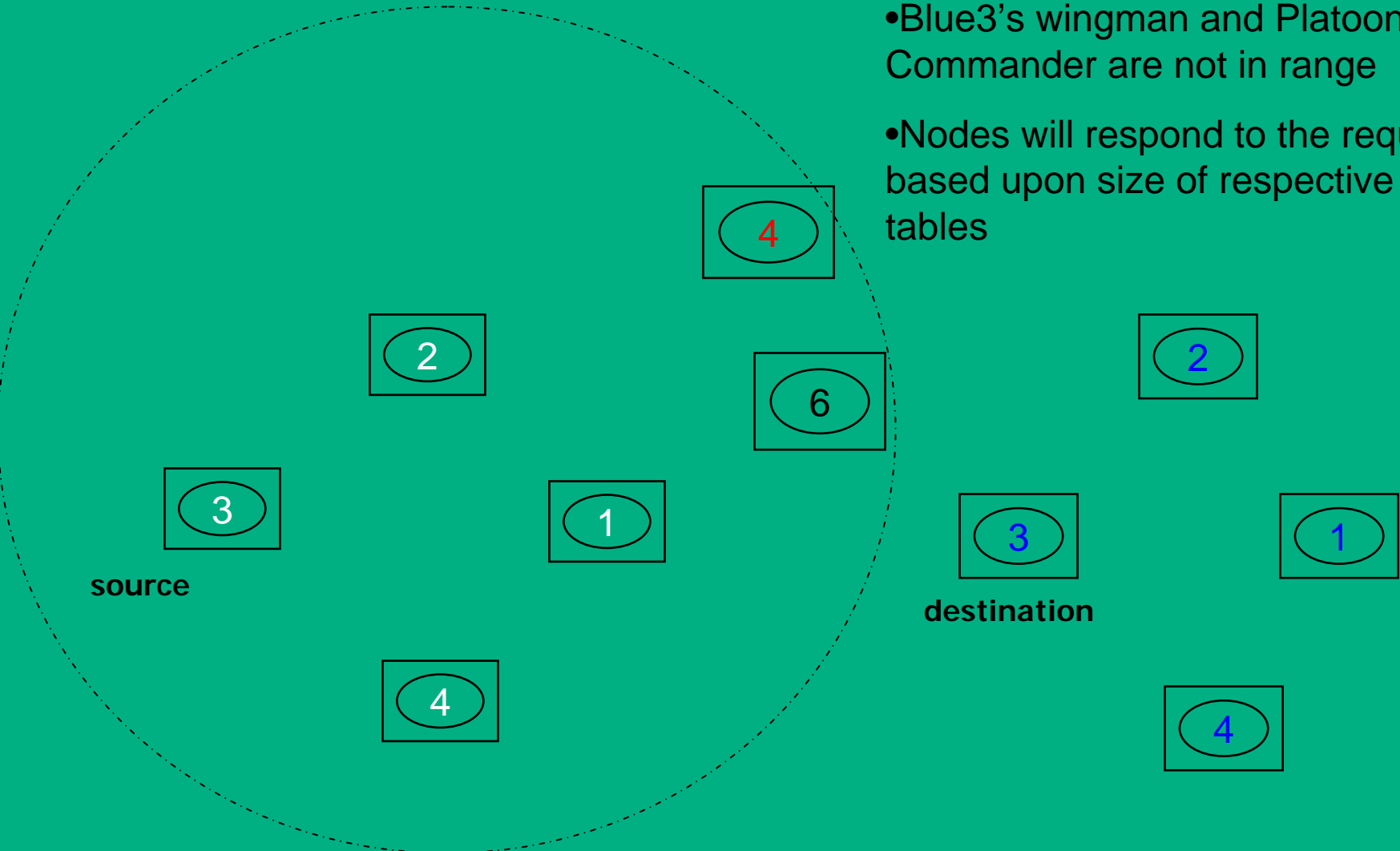
Congestion Avoidance

- Assume all within circle are within range of one another
- Route requests from White3, for Blue2



Congestion Avoidance

- Range of White3 is shown
- Blue3's wingman and Platoon Commander are not in range
- Nodes will respond to the request based upon size of respective routing tables

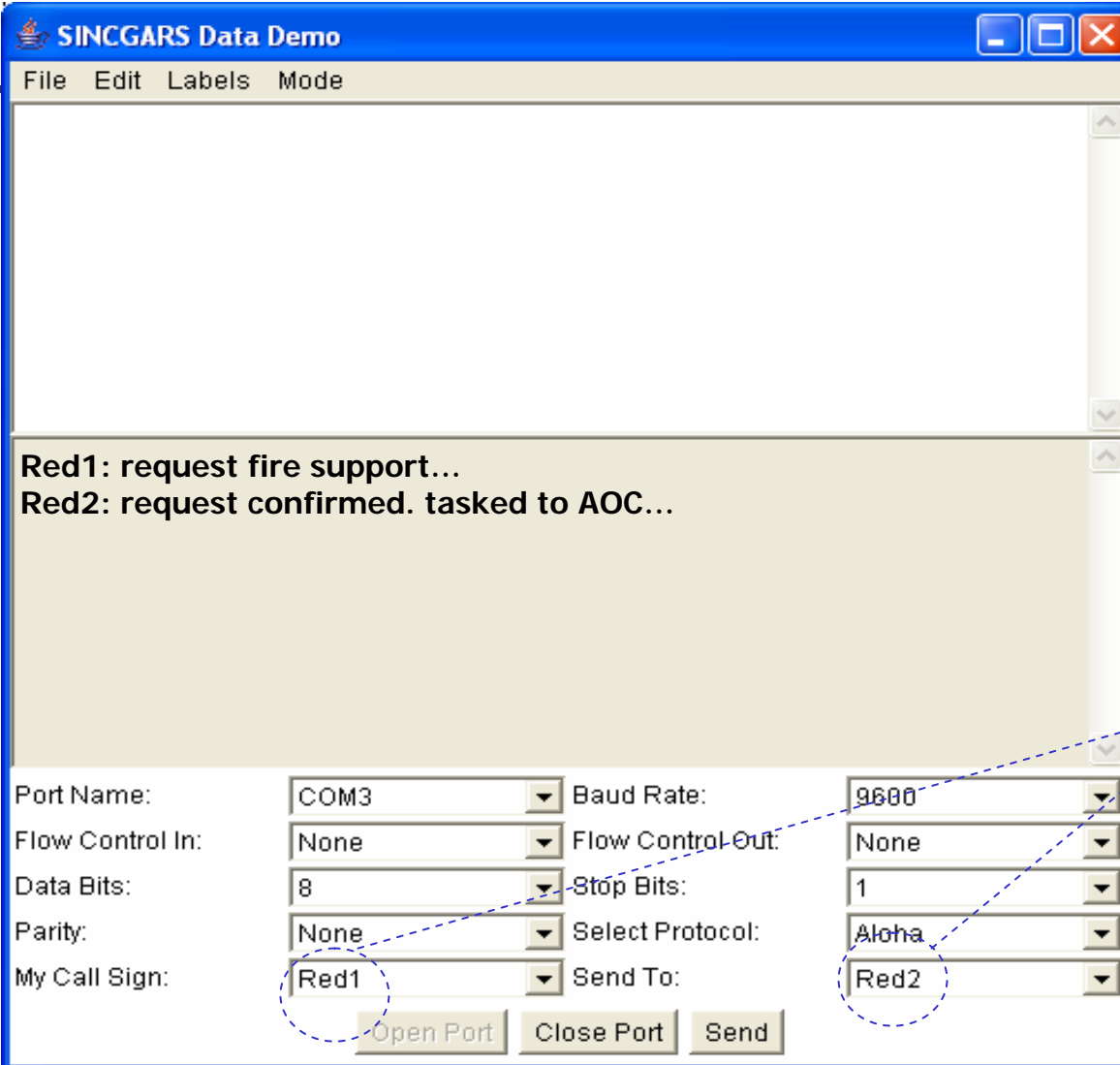




SINGARS Data Demo

- Tactical Chat Application
- File Transfer Capability
- Runs Directly Above Link Layer

SINGARS Data Demo



The image shows a screenshot of the 'SINGARS Data Demo' application window. The window has a blue title bar with the text 'SINGARS Data Demo' and standard Windows window controls (minimize, maximize, close). Below the title bar is a menu bar with 'File', 'Edit', 'Labels', and 'Mode'. The main area of the window is a large text field. It contains two lines of text: 'Red1: request fire support...' and 'Red2: request confirmed. tasked to AOC...'. Below the text field is a section for configuring the serial port. It includes labels for 'Port Name:', 'Flow Control In:', 'Data Bits:', 'Parity:', and 'My Call Sign:'. Each label is followed by a dropdown menu. The 'Port Name' is set to 'COM3', 'Flow Control In' is 'None', 'Data Bits' is '8', 'Parity' is 'None', and 'My Call Sign' is 'Red1'. To the right of these are labels for 'Baud Rate:', 'Flow Control Out:', 'Stop Bits:', 'Select Protocol:', and 'Send To:'. The 'Baud Rate' is '9600', 'Flow Control Out' is 'None', 'Stop Bits' is '1', 'Select Protocol' is 'Aloha', and 'Send To' is 'Red2'. At the bottom of the window are three buttons: 'Open Port', 'Close Port', and 'Send'. A dashed blue line points from the text 'Call signs reflect node relationships...' to the 'Red1' and 'Red2' call sign dropdowns.

SINGARS Data Demo

File Edit Labels Mode

Red1: request fire support...
Red2: request confirmed. tasked to AOC...

Port Name: COM3 Baud Rate: 9600
Flow Control In: None Flow Control Out: None
Data Bits: 8 Stop Bits: 1
Parity: None Select Protocol: Aloha
My Call Sign: Red1 Send To: Red2

Open Port Close Port Send

Call signs reflect node relationships, e.g., Red1 and Red2 are wingmen to each other.



Conclusions

- Demonstrated feasibility to deploy data centric C2 capabilities with legacy voice centric radios using *only* software
- Many opportunities exist to develop low cost *stop-gap* C2/network centric capabilities for front line troops